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The effect of fluid chemistry on quartz microcrack lifetimes

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Abstract

Metamorphic porosity consists of a branching hierarchy of primary features (grain boundaries), secondary features (3- and 4-grain junction tubules), tertiary features (microcracks), and higher order features (fractures). While some of these features are rarely open to bulk fluid flow (e.g. boundaries), higher order features are open to fluid flow for timescales which vary significantly as a function of temperature, pressure, and fluid and rock chemistry. The kinetics of microcrack healing in quartz between 300–600°C at 200 MPa increases as a function of fluid chemistry in the following order: $\text{CO}_2\text{---H}_2\text{O} < \text{H}_2\text{O} < 1\text{ m NaCl} \approx 2\text{ m CaCl}_2 \approx 6\text{ m NaCl}$. Changes in fluid chemistry which increase quartz solubility correlate with increased rates of healing. These observations suggest that local redistribution of quartz occurs by solution-precipitation driven by gradients in curvature along the crack surface, and is possibly rate-limited by pore-fluid diffusion. However, the effect of crack geometry is larger than the effect of fluid chemistry. At elevated temperatures and pressures, aqueous fluids with elevated NaCl concentrations can penetrate pervasively into polycrystalline quartz along a branching hierarchy consisting of episodically open fractures connected to 3- and 4-grain junction tubule networks, while pure water or $\text{H}_2\text{O}\text{---CO}_2$ fluid can only infiltrate pervasively along episodically open fractures [1]. At lower temperatures and pressures, 3- and 4-grain tubule networks in polycrystalline rocks may be closed to all fluids, limiting fluid infiltration to microfracture networks. Lifetimes of quartz microcracks in all these fluids ($P_{\text{fluid}} = P_{\text{confining}}$) is geologically short even at temperatures as low as 200°C.



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